MULTI-SENSOR FUSION FOR UAS GROUND-BASED DETECT AND AVOID CAPABILITY

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Abstract

In order to safely and seamlessly integrate UAS into non-segregated airspace, a robust DAA capability needs to be established. The New York Griffiss International Airport Unmanned Aircraft Systems (UAS) Test Site is evaluating next-generation UAS ground-based detect and avoid (GBDAA) systems capable of enabling extended UAS beyond line-of-sight (BLOS) operations in airport terminal areas and in transition airspace. GBDAA is an important research area in the current Phase Two of RTCA Special Committee 228 (Minimum UAS Performance Standards), which focuses on civil UAS equipped to operate under IFR flight rules in extended UAS operations in Class D, E, and G, airspace, down to but not including ground operations. The Griffiss UAS Test Site has set up an instrumented test range for air traffic surveillance, extending from the Griffiss airport and its Class D airspace to about 40 NM to the north. The Griffiss range instrumentation system employs multi-sensor fusion using a combination of wide area multilateration, ADS-B, and primary radar to track cooperative and noncooperative air traffic. The system is designed to operate in combination with other air traffic surveillance sensors, including airborne DAA sensors. Griffiss test range instrumentation provides real-time air traffic surveillance, with an ability to incorporate simulated air traffic. The system incorporates a data collection, storage, and analysis capability for building the safety for UAS integration into terminal and transition airspace, and supports live, virtual and constructive simulation in distributed environments (LVC-DE). To understand the system and its uses, it is important to keep sight of reasons for capabilities such as those under development at the Griffiss UAS Test Site. The paper concludes with a description of an example of how multi-sensor fusion in the Griffiss range instrumentation system might be employed to make a safety case of beyond line-of-sight UAS operation in Griffiss test range airspace.

Introduction

Griffiss International Airport (Griffiss) is one of seven FAA-designated national U.S. test site operators authorized under the FAA Modernization and Reform Act of 2012 (FMRA of 2012).

Griffiss is a public-use airport, owned and operated by Oneida County, New York. Located in Rome, NY, Griffiss has an 11,800 foot runway, an operating air traffic control tower, and ample airspace for UAS test operations. The Griffiss industrial park is home to the Air Force Research Laboratory Information Directorate (AFRL Rome Lab). The New York Air National Guard conducts extensive large UAS operations in northern New York airspace.

Under a teaming agreement with Griffiss, the Northeast UAS Airspace Integration Research Alliance (NUAIR Alliance) acts as Griffiss UAS test site manager, responsible to the FAA and Griffiss for operational control and program management for UAS testing at Griffiss test ranges in New York, Massachusetts, and Northern Michigan. The NUAIR Alliance is a Syracuse, NY, headquartered, not-for-profit corporation representing an alliance of over 100 industry and academic partners. The NUAIR Alliance is led by CenterState Corporation for Economic Opportunity (CenterState CEO) in Central New York, and the Massachusetts Development Finance Agency (MassDevelopment) in the Commonwealth of Massachusetts.

The FAA in 2013 selected Griffiss International Airport to receive, from among 25 applicants, a designation as a national UAS flight test site. In selecting six new UAS test sites in late 2013, the FAA noted that Griffiss "plans to work on developing test and evaluation as well as verification and validation processes under FAA safety oversight." Griffiss "plans to focus its research on sense and avoid capabilities for UAS and its sites will aid in researching the complexities of integrating UAS into the congested, northeast airspace."

Griffiss UAS Test Site Mission

The Griffiss mission under the FAA UAS test site program is to contribute to FAA development of procedures, standards and regulations necessary to support safe integration of UAS into the national airspace system (NAS). The FAA requires UAS test site flight operations to be performed in civil airspace. Persistent testing and extensive proving flights will be required to support development of safety standards for routine UAS operations in the NAS and to establish the "safety case" for alternative means of compliance with manned aircraft operation and certification standards.

To support this mission, the Griffiss UAS Test Site provides industry, the FAA, and other government agencies a resource for development, under FAA supervision, of safety cases and operational capabilities for integrated manned and unmanned operations in the NAS.

Griffiss Range Instrumentation

In 2014, New York State awarded NUAIR funding for initial phase one test range instrumentation, with ground-based surveillance (multilateration, primary radar, and ADS-B) covering Griffiss Class D airspace and test ranges extending north for approximately 40 NM and from the surface through Class A airspace. Expansion of the initial instrumented airspace is planned for future phases.

The purpose of Griffiss range instrumentation is capability development for measurement and recording of position, velocity and track information for airborne activity in and around Griffiss test ranges, and to support GBDAA development. The engineering design philosophy for Griffiss range instrumentation is for operation at a high Technology Readiness Level (TRL). An initial NUAIR requirement in proposing the system was that system components must be in current operation in the NAS, in civil airspace globally, or be components of a program of record for GBDAA applications.

Griffiss range instrumentation is based on four high TRL technology capabilities:

Airport Surface Detection Equipment-Model X (ASDE-X) and Airport Surface Surveillance Capability (ASSC)

- FAA use as safety systems in major airport ATC towers (ATCT). ATCT displays provide situational awareness to the controllers
- Displays and audio provide alerts in the event of a potential collision hazard. Data recording for incident investigation
- Provides surveillance to runway status lights (RWSL)
- Provides surveillance to FAA Surveillance and Broadcast Services (SBS). Provides surveillance to STARS for Precision Runway Monitor-Alternative (PRM-A)
- Data distributed via NAS Enterprise Security Gateway (NESG) and SWIM Terminal Data Distribution System (STDDS)

Wide Area Multilateration (WAM)

- Used for ATC in Colorado and Juneau
- Integrated ADS-B (1090ES and 978 UAT)
- Active Mode 3/A transponder interrogation

Lightweight Surveillance and Target Acquisition Radar (SRC LSTAR®)

- 3-D, 360-degree situational awareness, electronically steered antenna
- Tracks non-cooperative and slow-moving airborne targets, while suppressing stationary and wind turbine clutter
- All-weather operation, small footprint, low power consumption
- Primary U.S. Army GBSAA sensor

Airport Surface Surveillance Radar

- X-band solid state, fully redundant, greater than 500 target capacity
- Data/signal clutter and multipath rejection,

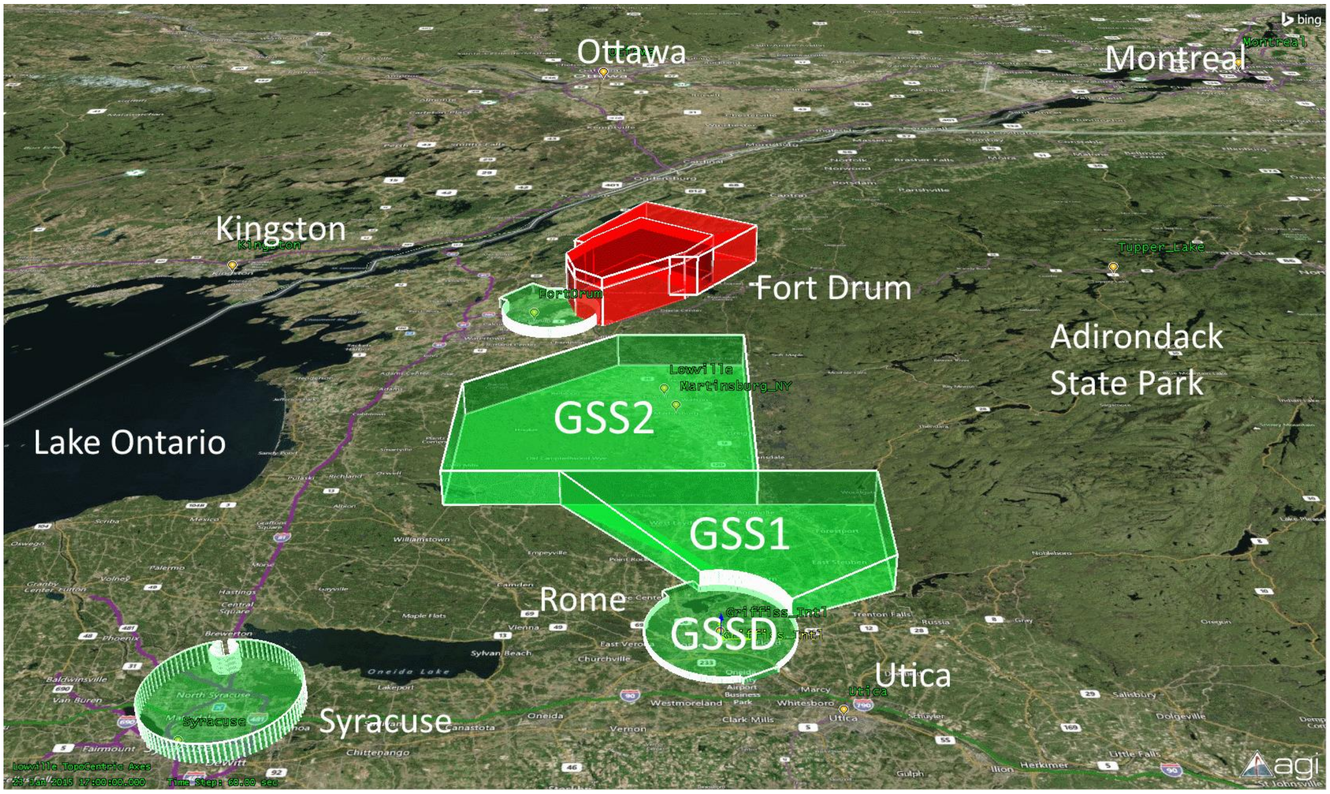


Figure 1 Primary Griffiss New York UAS Test Ranges

Airspace

Figure 1 shows primary Griffiss test ranges, together with Syracuse Class C airspace and Class D and restricted airspace at Wheeler-Sack Army Airfield, Fort Drum, New York.

The three Griffiss range areas (GSSD, GSS1, and GSS2) represent Griffiss Class D airspace, a transition area (GSS1), and a northern extension (GSS2). The GSS2 extension partially overlays an existing military operations area and is designed to support extended UAS operation in Class E and G airspace and Class A airspace above FL 180.

Griffiss holds an FAA Certificate of Waiver or Authorization (COA) to operate large UAS in the GSS airspace. Class G, D, E and A are all included in the COA. There are five ATC facilities having jurisdiction over this airspace (Griffiss Airport Traffic Control Tower, Syracuse Airport Traffic Control Tower, Wheeler-Sack Radar Approach Control and Boston Air Route Traffic Control Center). A Letter of Agreement (LOA) between the ATC facilities, Griffiss, and the FAA Air Traffic Organization defines responsibilities, procedures and coordination requirements for UAS operations performed under the Griffiss Test Range COA.

Establishing Baseline Requirements

The original baseline requirement for Griffiss range instrumentation was to employ wide area multilateration (WAM) capability to locate aircraft transponder transmissions on 1090 MHz through a standard time-difference-of-arrival (TDOA) method. Multilateration provides core surveillance for Advanced Surface Movement Guidance and Control Systems (A-SMGCS) currently in use by air navigation service providers (ANSPs) worldwide. A-SMGCS is a modular system using fused surveillance sources and safety logic for prevention of runway incursions and safe and expeditious movement of aircraft at airports and in the terminal area, and ground vehicles in the movement area.

A-SMGCS is defined by ICAO in Reference [1] as “a system providing routing, guidance and surveillance for the control of aircraft and vehicles in order to maintain the declared surface movement rate under all weather conditions within the aerodrome visibility operational level (AVOL) while maintaining the required level of safety.”

There are two main A-SMGCS variants in U.S. use today: Airport Surface Detection Equipment, Model X (ASDE-X), and Airport Surface Surveillance Capability (ASSC). Reference [2] describes ASSC and refers to the FAA ASDE-X system specification.

The relevance of A-SMGCS as a basis for robust UAS GBDAA is that the system, while mainly deployed at major airports for surface safety applications, in practice also provides accurate airspace surveillance (in the case of ASDE-X out to 5 miles for approach corridors) in the terminal area.

Wide Area Multilateration uses additional multilateration remote units to extend coverage. For example, when multilateration supports Precision Runway Monitoring (PRM-A) for closely-spaced parallel approaches, multilateration sensors are located along and around the airport approach corridors 30 or 40 miles beyond the runway thresholds. Reference [3] provides FAA guidance for the use of PRM-A multilateration information for conducting ATC separation services at Detroit TRACON (D21) using the STARS automation platform operating in Fusion Display Mode (FDM).

A. ASDE-X System Capabilities

ASDE-X, has been effective in reducing runway incursions and improving situational awareness for tower cab air traffic controllers. In addition to these primary benefits, ASDE-X has “safety logic” to extend the safety features of the system.

The ASDE-X system is comprised of four basic subsystems: surveillance sensors and sources, data fusion processing, safety logic, and the Controller Working Position (CWP).

Surveillance sensors and sources comprise three types: existing terminal surveillance radar (TSR) providing both primary and secondary airspace coverage to 60 NM; surface movement radar (SMR) providing primary coverage for the airport surface; and multilateration providing secondary coverage for the airport surface. Additionally, multilateration receives and processes ADS-B aircraft position reports from equipped aircraft via the Mode-S extended squitter protocol.

Data fusion processing collects and processes the position reports from each of the surveillance sensors and sources and fuses the data to produce tracked aircraft targets.

The fused tracks for all aircraft are analyzed by the safety logic sub-system to identify potential safety conflicts between aircraft, between aircraft and surface vehicles, and between aircraft and protected airport surfaces like the active runway. Any potential conflict is displayed on the CWP for appropriate controller action.

In addition to advising controllers on potential conflicts, the CWP provides a comprehensive 2-D view of the airport surface with all cooperative and non-cooperative aircraft and vehicle targets displayed and tracked. The CWP is refreshed at a 1 Hz rate by the data fusion processor based on the high update rate of the multilateration and SMR surveillance sources. Between the CWP update rate and the inherent accuracy of multilateration, tower cab controllers are provided an accurate and timely depiction of airport surface movement and state.

The ASDE-X system has two inherent capabilities–operational recording and playback and external surveillance data sharing via the Data Distribution (DD) cabinet. Operational recording and playback is used for incident analysis and system status, monitoring, and assessment. The DD supports a firewall filtered and real-time stream of ASDE-X surveillance data to third parties.

Taken as a system, ASDE-X provides the following fundamental capabilities:

1) 2-D Airport Surface Situation CWP Display
2) Controller Conflict Alerts
3) Surveillance and System Data Recording
4) Surveillance Data Distribution

In practice, tower cab controllers rely on the CWP and conflict alerts to safely move aircraft from movement area transition spot to runway and from runway to transition spot. Operations and maintenance personnel depend upon the system status and recording capabilities to ensure a high level of system availability.

The Griffiss instrumentation system employs a standard ASDE-X platform, with operational status monitoring, recording, and maintenance features.

The Case for Multilateration

The common pillar on which ASDE-X, ASSC, and the Griffiss range instrumentation all rest is multilateration. Multilateration provides accurate position and identification information on transponder-equipped vehicles in the air and on the surface by pinpointing the location of signals transmitted by aircraft or vehicle transponders. Multilateration is the process of determining a transponder's location by solving for the mathematical intersection of multiple hyperbolas (or hyperboloids) based on difference between arrival times of a transponder's signal at multiple sensors. For determining altitude, multilateration relies primarily on altitude information provided by aircraft avionics, although transponder altitude as well as location can be measured with 4-sensor coverage.

Multilateration is a proven surveillance technology which works by employing multiple remote sensors throughout an area to determine transponder-equipped aircraft position and identification. This data is processed for ATC use to provide surface and terminal area surveillance and en route separation services. The first U.S. sites to receive multilateration systems for ATC-provided 5 NM separation services were Juneau, Alaska, and Yampa Valley, Craig-Moffat, Steamboat Springs, Garfield County Regional airports in Colorado.

In the U.S., multilateration systems receive and process target data on 1090 MHz and 978 MHz, providing target and track updates once per second. The 1090 MHz processing is done in accordance with RTCA DO-181D and DO-260B as a minimum operational performance requirement. UAT processing follows RTCA DO-282B.

Mode S and UAT transponders “squit”—automatically announcing their presence. Mode A/C ATCRBS transponders need to be actively interrogated before they respond—they do not automatically squit. The Griffiss multilateration system interrogates ATCRBS targets by transmitting on 1030 MHz so the system can “multilaterate” on their replies. The system also interrogates Mode S transponders to obtain their Mode A code.

The Griffiss multilateration system began operation in mid-2016. After extensive discussion with FAA and FCC review, at the end of 2016 Griffiss received an FCC experimental license for active 1030 MHz interrogation. The basis for this award was the importance of research leading to GBDAA system standards development.

Since a multilateration system can compare GPS-derived aircraft ADS-B position with the position derived from multilateration, a false track report can be generated. The FAA ASSC system specifies that a false track report be generated when the two positions differ by more than 100 feet on the airport surface and by more than 500 feet within 1.7 NM of the runway threshold.

Multilateration System Components

Multilateration Subsystem Sensors (MSS)

The multilateration subsystem uses two types of sensors – receiver/transmitter sensors and receive-only sensors. All Griffiss MLAT sensors have R/T capability, but most operate in receive-only mode. Both types receive, timestamp, and decode both Mode S and ATCRBS transponder reply signals, as well as UAT squits. Reply data is processed by the MSS software and communicated to the Target Processor (TP) via the communications infrastructure. The MSS transmitter sensors can also request information from transponders using scheduled interrogations commanded by the TP. Both MSS types feature ruggedized weatherproof enclosures designed for harsh outdoor environments. The quantity and placement of each type of MSS is based on the desired coverage area, performance requirements, and reliability needs.

Figure 2 MSS Sensor (Remote Unit)

Target Processor (TP)

The fully redundant, auto-switching TP is the central computer that collects transponder reply information from all MSSs. The software computes target positions and tracks multilateration targets. The TP also monitors the status and health of all multilateration components and schedules transponder interrogations as required.

GPS Independent Time Reference

Redundant GPS independent time reference units provide high-accuracy system synchronization and stimulation of system-wide built in test (BIT) functionality. Each unit, packaged in a ruggedized weatherproof enclosure; features redundant transmitters to ensure ultra-high reliability for this critical subsystem. The system includes a means for identifying and isolating synchronization problems. The Multilateration Subsystem Sensor clocks drift apart. Using the reference unit squits, system periodically estimates the difference between the predicted and measured time difference arrivals between Multilateration Subsystem Sensors. If test targets are not included in the system and the time reference transmits a UAT squit, Mode S squit, or ATCRBS reply, then the reference units are used as test targets.

Communications Infrastructure

Multilateration systems are designed to handle flexible data communication interfaces. Data may be transmitted from the MSSs to the TP over wired or wireless serial data modems, fiber, an Ethernet LAN, or a combination of these data links. Single or redundant communication links can be provided depending on reliability requirements.

Multi-Sensor Data Processor Subsystem

Fusion occurs in the Multi-Sensor Data Processor (MSDP) Subsystem. The MSDP subsystem processes all surveillance sources, performs tracking and identification functions, handles surveillance and tracking control, and provides output to the Display subsystem. The MSDP tracks air and surface targets of interest in the form of plot and track data is processed by the MSDP subsystem to track and identify targets within the multilateration coverage volume. GPS-based position measurements from ADS-B equipped targets can also be provided to the MSDP. This data may be supplemented by plot and/or track data from primary radar or beacon sources. The MSDP can also support automated and manual tagging of targets as well as conflict alerting in the form of Safety Logic.

Fusion Algorithms

The MSDP relies on a data base of sensor coverage and false detection characteristics, and provides filtered, normalized and aligned data for combination. The fusion algorithm is designed to provide "seamless coverage," a single picture combining all source data and maintaining track and ID continuity. Fusion processing provides fused track data that is as good as or better than the best individual sensor track of a target in terms of accuracy and timeliness. It also ensures that a single fusion track is maintained for each target as long as it is detected by any supporting sensor in the coverage volume. The fusion process compensates for intersensor bias errors such as radar static range/azimuth bias and applies an adaptable time adjustment to all reports from each sensor to account for communication delays within the system. In addition, the fusion process continuously estimates and corrects for the mean bias between the multilateration and ADS-B measurements for aircraft that are seen by the multilateration subsystem and ADS-B or SBS inputs. The MSDP, in conjunction with sensor subsystems, prevents the display of false tracks. The MSDP provides track history and supporting sensor data to allow user evaluation of fusion decisions, and for verification and validation of fusion algorithms (a capability that will likely become important for verification and validation of UAS DAA and CA algorithms).

Safety Logic

In systems such as ASDE-X or ASSC, the MSDP implements “Safety Logic” functionality. Safety Logic provides warning via the display subsystem of potential collision situations. The superior target data quality made possible by the fusion processor provides the best possible information to drive Safety Logic. In A-SMGCS, Safety Logic propagates targets into the future, assigns the targets to surfaces (such as a runway or taxiway), and establishes a movement state and direction state for each target. Predicted runways are calculated for each arriving aircraft. Safety Logic checks the separation between current and projected target positions and detects any targets that violate current or projected separation thresholds. Alerts are generated and sent to the display subsystem for any violations that are detected. Various alert situations are detected by Safety Logic, based upon what the involved aircraft are doing in the air and/or on the ground (e.g. an aircraft is arriving to a runway occupied by a taxiing aircraft, or an aircraft departing on a taxiway or closed runway). In the ASDE-X display system, an alert causes the subsystem to display red octagons around each aircraft or vehicle involved in an alert, and the icons for the involved aircraft or vehicles flash on and off. A text box displays the call sign or Mode S identifiers of the aircraft or vehicles, along with a description of the violation. In addition, a configurable audible message is rendered which can specify information such as the runway or taxiway, the call signs or Mode S IDs of aircraft or vehicles, a description of the violation, and instructions to the controller. For ASDE-X and ASSC systems, this combination of audible and visual information provides information necessary for the controller to take immediate action.

Systems combining multilateration with MSDP can support highly accurate surveillance (within ±18 feet of ground truth on the airport surface for ASDE-X) at one-second refresh rates. Such systems are able to support transponder-equipped aircraft (including UAS) on the airport surface, in Class D airspace, in extended operation in Class E airspace, and along transit corridors to and from Class A airspace. To track non-cooperating targets, primary radar fusion must supplement multilateration. In the ASDE-X system, this function is provided by X-band airport surface movement radar (SMR). For UAS GBDAA purposes, primary radar surveillance to accompany multilateration may be in the form of one or more small 3-D radars. GBDAA multilateration ground stations and small primary surveillance radars can be completely independent of NAS systems, serving to support the UAS ground control station.

Primary Radar

In the RTCA SC-228 UAS standards development process, the FAA UAS Integration Office and major UAS Stakeholders are working closely with the UAS community to develop the Minimum Operational Performance Standards (MOPS) for DAA equipment. The operational environment for the SC-228 Phase Two MOPS is extended UAS operations in Class D, E, and G, airspace, down to but not including ground operations.

The RTC SC-228 DAA work group is currently defining the scope of Phase Two GBDAA MOPS. The scope will likely include MOPS for ground-based non-cooperative primary radar. Specific technology, to include architectural considerations and operational concepts will be defined in the SC-228 DAA Phase Two White Paper due in July 2017.

LSTAR Radar

Recognizing in 2014 that primary radar surveillance fusion is necessary to identify and track non-cooperating targets, the current Griffiss range instrumentation incorporates 3-D primary radar fusion, using an SRC LSTAR radar. The SRC LSTAR family of air surveillance radars provides 360 degree, 3-D electronic scanning capabilities for detecting and tracking airborne targets. These radars are capable of detecting and tracking UAS, fixed and rotary wing aircraft, such as ultralights, paragliders and hang gliders. LSTAR systems are in use as sensors for border air surveillance, critical infrastructure protection, local airspace management, wind farms, and UAS airspace integration.

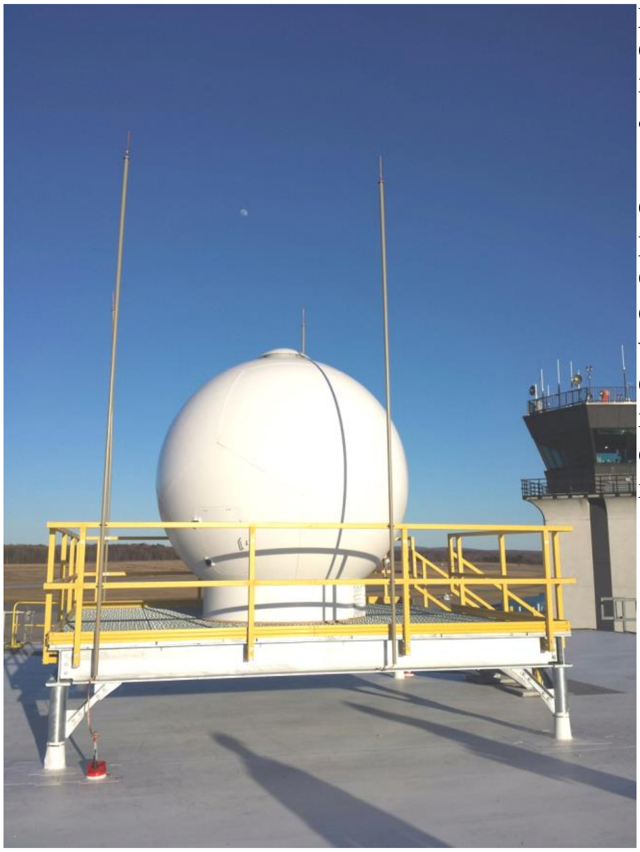


Figure 3 LSTAR Radar Installed at Griffiss

. System Logical Architecture

Figure 4 below illustrates the Griffiss range instrumentation system architecture. This represents a foundation for a flexible architecture for Griffiss range instrumentation. Flexibility was considered to be an important design consideration, so that different sensors could be combined and sensor fusion performed in different ways; many of which we are unable to anticipate today. Data will need to be captured, archived, retrieved, and analyzed in different ways. Information will also need to be displayed and incorporated into decision support tools in many different ways. For example, while the system architecture illustrated in Figure 4 represents a WAM-based approach, it incorporates several primary radars (LSTAR and SR-3). An original design requirement for the Griffiss range instrumentation project was that the system would be able to evolve as a test bed for GBDAA.

The system architecture in Figure 4 reflects this design approach, employing an independent processing suite driven by primary radar for detection of both cooperating and non-cooperating targets, other sensors capable of tracking cooperating target with high accuracy, and a highly-capable fusion engine to derive accurate time, space, and position information. The architecture is also designed for conformance monitoring and incorporation of intent information.

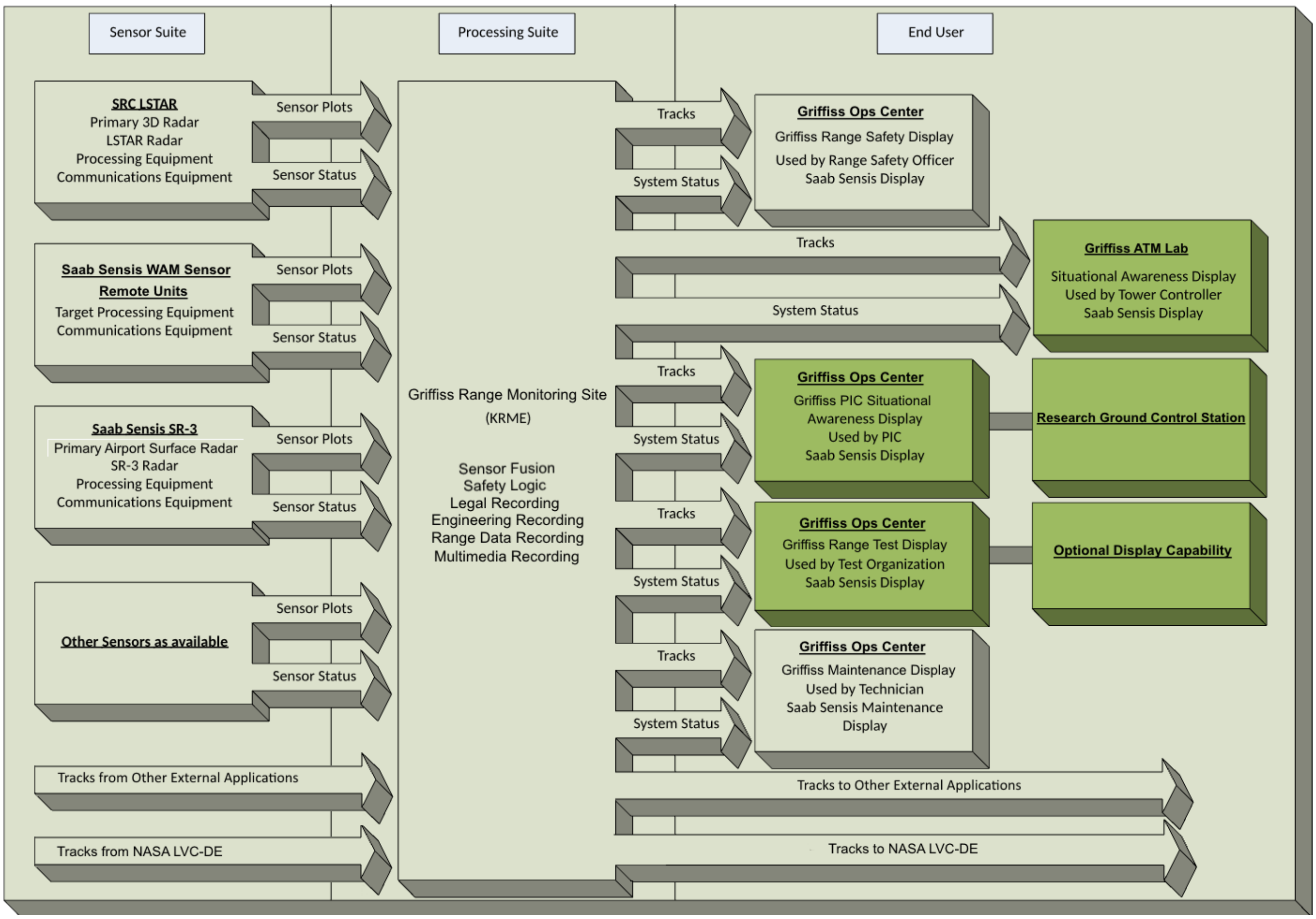


Figure 4 Griffiss WAM-Based Instrumentation System Architecture

The system architecture depicted in Figure 4 is based on the ASDE-X architecture and retains the proven sensor fusion ability, legal recording, system and health monitoring, and redundancy of ASDE-X. The system performs four basic functions:

- Sensor output plotting and status reporting
- Sensor fusion, processing, and data capture
- User display and decision support
- System maintenance and reliability support

Sensor Suite

The Griffiss range instrumentation system is designed to support and incorporate a variety of sensors and sensor feeds. These can be ground-based or airborne feeds, are not limited to direct feeds. Illustrated in Figure 4 above are feeds from NASA live, virtual, constructive-distributed environment (LVC-DE) and Harris RangeVue track inputs.

Reference [4] provides background on the NASA approach to LVC-DE. The NASA UAS Integration in the NAS Project is comprised of ATC, constructive and virtual aircraft simulators, and UAS ground control stations (GCS) which together provide a representative unmanned environment. The term LVC is broadly used for classifying modeling and simulation (M&S). For specific flight tests or simulations a subset of available live assets and software components can be integrated to form an LVC instance. The NASA LVC test environment incorporates technologies and concepts developed by NASA and external partners into the simulation or flight environment.

Griffiss has committed to integrate its range instrumentation system with the NASA LVC-DE partnership.

Fusion, Processing, and Data Capture

In 2014, building a test range instrumentation system employing a proven platform such as ASDE-X was a low risk approach which provided a significant advantage over other options. ASDE-X was a mature system with over 15 years' experience supporting FAA NAS operations, with built-in redundancy, system and health monitoring, maintenance, and troubleshooting capabilities. The sensor fusion, legal recording, and status monitoring meet operational requirements and standards, exceeding test range R&D requirements. The ASDE-X safety logic capability was considered to be a feature which could be adapted to meet UAS GCS needs. The use of standards-based sensor track data in the Griffiss system conforming to the EUROCONTROL ASTERIX specification for surveillance data exchange, as specified in Reference [5] was considered to be a significant benefit derived from the both multilateration and primary radar sensors employed in the system.

Building on the basic platform, future GBDAA data archiving, display, retention, and analysis will require much more than the functions supported by the basic ASDE-X system. The amount of both live and simulated air traffic surveillance data, generated by the Griffiss UAS test range, and considered to be necessary to establish the safety case for UAS SAA and collision avoidance, will extend beyond what in the past has been found necessary to prevent runway incursions. Griffiss and NUAIR recognize that data management and analytical support will be a significant challenge. Reference [6] discusses a proposed "big data" approach to this challenge.

Highly accurate time and position determination, able to function without complete dependence on GNSS, can be considered to be a necessity for operation of a system which supports test range instrumentation and serves as a research GBDAA system. Fusion of data captured from several different sensors and LVC inputs will be affected by latency. Due to asynchronous sensor inputs and the distributed nature of the LVC test environment, latencies of messages passed between the LVC components in different simulations and locations will need to be characterized to understand latency effects in integrated simulations. In addition, in order synchronize live, virtual, and constructive data, it will be critical to understand, mitigate, and work with latency which occurs between various distributed components of an LVC test environment.

User Display and Decision Support

User displays and decision support tools (DSTs) are not readily transferable from ASDE-X/ASSC applications, and will need to be developed to meet specific UAS operational requirements.

Representative user displays are portrayed as boxes in Figure 4. Griffiss has equipped a UAS operations center and ATC laboratory to support various test displays for range safety and test management, system health and performance monitoring, uptime and maintenance management, as well as simulated ATC and pseudo-pilot work positions. The Griffiss UAS operations center will support research into situational awareness, safety logic, and alerting for 3-D GCS representations.

System Maintenance and Reliability Support

Griffiss range instrumentation, built on ASDE-X, incorporates maintenance, reliability, and redundancy features integrated into ASDE-X. In this area Griffiss will be able to leverage capabilities of the basic ASDE-X system to great advantage.

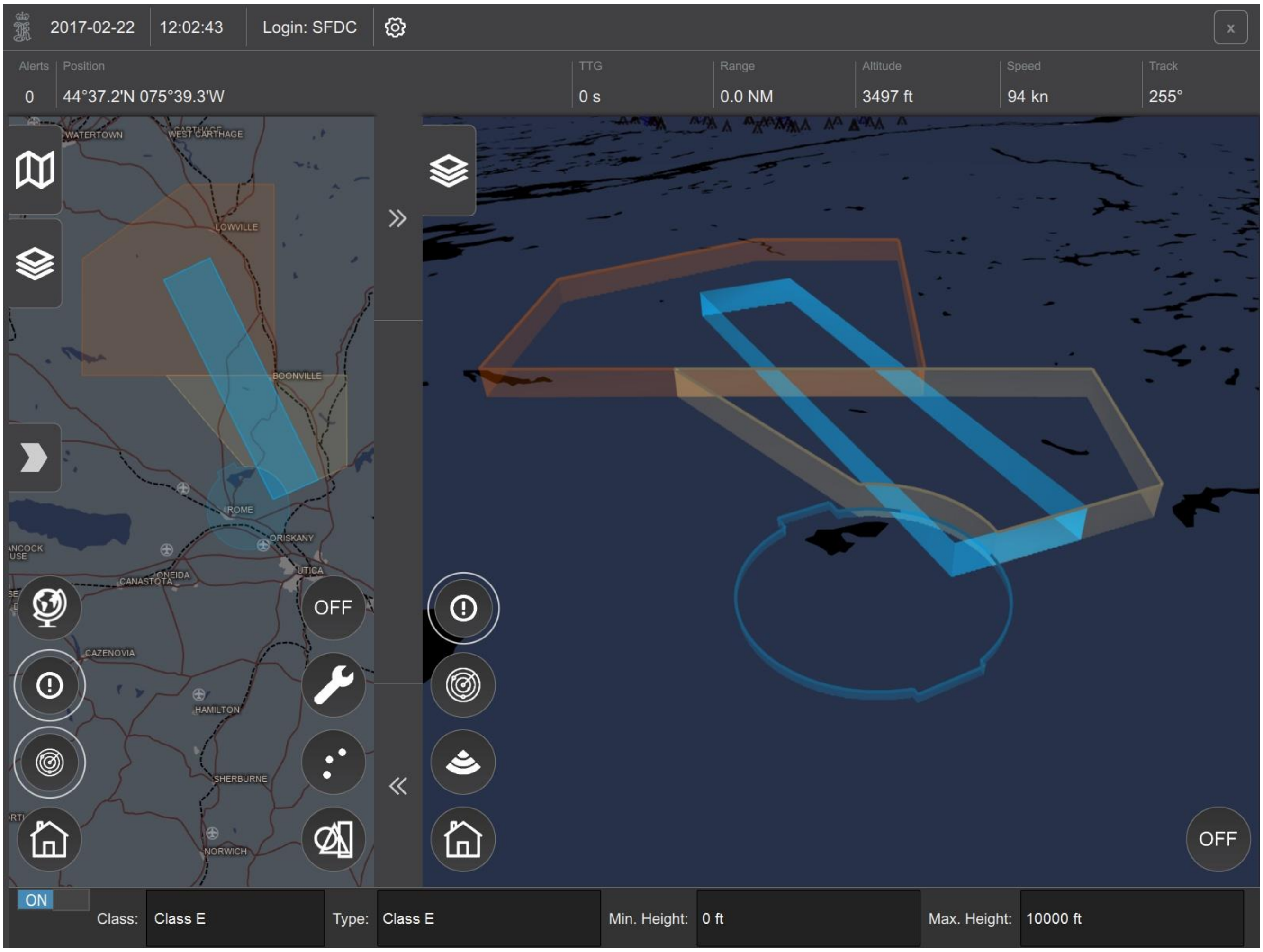
The Beyond Line-of-Sight Challenge

It is important to keep sight of the reason for development of capabilities such as those under consideration at the Griffiss UAS Test Site. A relevant question is how the Griffiss range instrumentation system might be employed as a research GBDAA system to enable beyond line-of-sight UAS operation. The description here complies with Griffiss UAS Test Site COA requirements [7].

The proposed approach is intended as an example of safety case development for UAS BLOS operation in Griffiss test range airspace, using primary radar and ground-based multi-sensor fusion.

The metric for success would be FAA issuance of a COA to Griffiss allowing BLOS UAS operation.

The proposed test would use a defined UAS operational corridor within current Griffiss COA airspace, as illustrated in Figure 5. The proposed test corridor, depicted in Figure 5, would be 30 miles in length and six miles across, and extend from Griffiss Class D airspace to the north to an altitude of 10,000 feet AGL. Test corridor surveillance coverage would include a Griffiss-operated network of primary radar, ADS-B, and multilateration remote units.



Airspace visualization by Kongsberg Geospatial

Figure 5 Griffiss Beyond Line-of-Sight Corridor

The test plan would include evaluation of three cases involving air traffic detection and tracking in the test range region: (a) ground-based primary radar only to detect both cooperating and noncooperating traffic, (b) ground-based multi-sensor fusion, combining available Griffiss surveillance sources (including primary radar), and (c) extending the first two test cases to include representative airborne sensors. The safety case for the initial test phase would assume ground-based surveillance only.

Preliminary data gathering would measure surveillance coverage and accuracy in the test corridor. The Griffiss air traffic surveillance system would gather and archive data on ambient air traffic activity and weather conditions in the test corridor.

In the initial phase, manned aircraft or surrogate UAS could be used to facilitate surveillance coverage mapping as well as accuracy measurement. This would also support BLOS procedures and operational concepts development. Tests would be conducted in VMC. Operations could be conducted under ATC control or under IFR. Simulation and LVC-DE capability could be used to develop stress cases, using simulated UAS against simulated or actual observed air traffic. Surrogate or optionally-piloted (OPA) UAS operating IFR in a live environment would test ability to coordinate with ATC before executing "remain well clear" avoidance maneuvers. With simulated air traffic and simulated UAS, a simulated ATC function would be needed.

The proposed test plan would develop and evaluate methods for UAS to remain well-clear of other air traffic:

1. Zero conflict airspace—if the in-use surveillance system detects no conflicts in the corridor, the UAS would be authorized to continue mission profiles, else the UAS would abort the mission, execute an escape maneuver, move to a safe loiter area, coordinate with the tower, or return to base.
2. Maintain DAA well-clear coordination with ATC—if the in-use surveillance system detects an intruder aircraft within a defined distance and closure rate, the UAS remote flight crew would coordinate with ATC before executing an avoidance maneuver.
3. Maintain DAA well-clear guidance to remote flight crew—using a guidance algorithm, a traffic display would offer guidance to the flight crew on maneuvers to remain well-clear of traffic.

Conclusion

The problem addressed by the Griffiss instrumented test range is a requirement to develop safety-related data from live and simulated UAS flight test activities. Test range instrumentation and GBDAA systems require accurate instrumentation and the capability to perform extensive post-flight analysis of flight state and airspace activity data. To date, no UAS test site has developed the ability to provide such support for large IFR-equipped UAS operating in civil airspace.

Griffiss and NUAIR believe that creation of an instrumented test range is a step toward development of a future flight test capability which will lead to:

- Ability to support live and simulated UAS flight test activities in Class D, extended operations in Class E, and in transition to Class A airspace.
- Ability to offer a safe UAS test environment in the NAS at reasonable cost to different users for evaluation of different UAS platforms, sensors, ground control stations, human interfaces, and procedures.
- Ability to develop the data and experience necessary to establish the safety case necessary for a wide range of future civil UAS operations in the NAS.
- Ability to innovate and grow capabilities to support advanced research into operation of future remotely-piloted and autonomous UAS system operation.
- Ability to build critical mass in a civil center offering UAS flight test resources to support the aeronautical industry, Federally Funded Research and Development Centers (FFRDCs), and government aeronautical R&D activities.

As a designated national UAS test center, Griffiss believes this proof-of-concept approach is adapted to the needs of a rapidly evolving FAA and UAS industry, and is built on a strong instrumentation system and air traffic surveillance foundation. The Griffiss test site is located at an FAA-certified airport facility with access to airspace and air traffic control facilities able to safely accommodate UAS testing in the NAS. The Griffiss approach is built with scalability in mind and an ability to embrace and incorporate future sensors, modeling, simulation and operational concepts.

A measure of success of the Griffiss approach to instrumented test range development will be its ability to attract users, customers, and working partners. Ultimately, success will be measured by Griffiss contribution to FAA adoption and certification of regulatory standards for safe UAS integration into the NAS—standards which establish

UAS ability to comply the equivalent of manned aircraft standards, equaling or exceeding current manned aircraft safety levels. Stated another way, to create a safer system.

Success will depend on the pace at which UAS integration into the NAS occurs—in turn the pace of UAS integration in the NAS will depend on availability of capable UAS test sites like Griffiss to support UAS standards development and validation.

For UAS integration into the NAS, a secondary measure of success for the Griffiss approach will be its ability to spur others to emulate, innovate, and develop like capabilities.

References

[1] ICAO Doc 9830, "Advanced surface movement guidance and control systems manual," 2004 http://www.icao.int/Meetings/anconf12/Document%20Archive/9830_cons_en[1].pdf

[2] FAA, "Market survey airport surface surveillance capability (ASSC)," February 2010, https://faaco.faa.gov/attachments/Airport_Surface_Surveillance_System_Market_Survey_020110.doc

[3] FAA National Policy Order JO 7110.121, "Precision runway monitor-alternative (PRM-A) multilateration (MLAT) data for surveillance at Detroit TRACON (D21)," November 9, 2015, http://www.faa.gov/documentLibrary/media/Order/MLAT_Order.pdf

[4] Murphy, J., and Kim, S., "UAS-NAS live virtual constructive distributed test environment characterization report" Document No. UAS-04.05.0001.01, September 2013, http://nix.larc.nasa.gov/search.jsp?R=20140009125&qs=N%3D4294966753%2B4294959645

[5] EUROCONTROL, "All-purpose structured EUROCONTROL surveillance information exchange (ASTERIX) specification," November 12, 2015, http://www.eurocontrol.int/publications/all-purpose-structured-eurocontrol-surveillance-information-exchange-asterix

[6] Boci, E.S., Thistlethwaite, S., "A novel big data architecture in support of ADS-B data analytic," 2015, ICNS Conference, April 2015.

[7] FAA Form 7711-1 UAS COA Attachment 2015-ESA-120-COA-TS, February 2017

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